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SOLAR RADIATION PRESSURE TORQUES
AND GEOMAGNETIC EFFECTS
ON SATELLITE ORBITS:
AN ANNOTATED BIBLIOGRAPHY

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**SOLAR RADIATION PRESSURE TORQUES
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Compiled by
WILLIAM L. HOLLISTER

**SPECIAL BIBLIOGRAPHY
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ABSTRACT

The ninety-four references presented cover the following subjects: solar radiation pressure torques, geomagnetic torques, and disturbance torques from all sources in satellite orbits. The values of these torques are being investigated as a function of time and distance.

Search Completed November 1961

INTRODUCTION

An investigation is being made of the effect of solar radiation pressure torques, geomagnetic torques, and disturbance torques from all sources on satellite orbits. The values of these torques are being investigated as a function of time and distance.

Several methods are reported in the literature for orienting a satellite in its orbit by use of geomagnetic torques. Such methods include the interactions of a satellite with the magnetic field where the satellite is induced with a negative potential due to the interaction with ions and electrons. Another proposed method is the use of a self-generated magnetic field. The use of an attitude control motor which generates a torque by the action of the Earth's magnetic field on electric currents in the satellite is reported.

Methods are also reported for space vehicle stabilization by the use of focused solar radiation pressure. The radiation pressure forces are studied and the magnitude of the intermittent acceleration which results from the eclipsing of the satellite by the earth is discussed.

The main perturbations of a satellite orbit near the earth are those caused by the Earth's oblateness and the atmosphere.

The perturbations of Earth satellite orbits by the gravitational attraction of the sun or the moon are also discussed.

This bibliography reflects the holdings of the Technical Information Center, Lockheed Missiles & Space Company. Other sources used were:

ARS Journal 1943-1961

Aero-Space Science 1953-1961

Battelle Technical Review 1958-1961

REIC Access List 1957-1961

SPL Astronautics Information 1953-1961

1. Adams, J. J., and Brissenden, R. F.
SATELLITE ATTITUDE CONTROL USING A COMBINATION
OF INERTIA WHEELS AND A BAR MAGNET. November
1960, 42p. U. S., NASA TN D-626.

Study considering the use of inertia wheels in combination with a permanent bar magnet to supply control torques for a satellite. A command equation for the inertia-wheel control system is derived. A three-degree-of-freedom study indicates that inertia coupling and precession coupling have only small effects on the results. The use of a bar magnet to supply the necessary trimming moments to remove the momentum introduced into the system by aerodynamic moments was found to be successful in a typical case of a satellite in orbit. It is found that an error signal that consists of the sum of the attitude error, the attitude rate, and the integral of the attitude error commanding the angular velocity of the wheel can give good dynamic response and precise control. Single-degree-of-freedom bench tests generally verified the dynamic response predicted by the analytical study and demonstrated control within ± 9 arc-seconds of the reference attitude.

2. Adams, J. J., and Chilton, R. G.
A WEIGHT COMPARISON OF SEVERAL ATTITUDE
CONTROLS FOR SATELLITES. National
Aeronautics and Space administration,
Washington, D. C. NASA Memo 12-30-59L.
February 1959.

A brief theoretical study has been made for the purpose of estimating and comparing the weights of three different types of controls that can be used to change the attitude of a satellite. The three types of controls are jet reaction, inertia wheel, and a magnetic bar which interacts with the magnetic field of the earth. An idealized task which imposed severe requirements on the angular motion of the satellite was used as the basis for comparison. The results showed that a control for one axis can be devised whose weight will be less than 1% of the total weight of the satellite. The inertia-wheel system offers weight-saving possibilities if a large number of cycles of operation are required; whereas the jet system would be preferred if a limited number of cycles are required. The magnetic-bar control requires such a large magnet that it is impractical for the example application but might be of value for supplying small trimming moments about certain axes.

3. Allen, D.W.
Reversals of the earth's magnetic field.
NATURE (LONDON) v. 182, p. 467-70,
Aug 1958.

Numerical integration of the equations for two disk dynamos coupled to one another shows that reversals of the current in their coils can occur under a wide range of conditions. Some implications of this result in connection with reversals of the earth's magnetic field are considered.

4. EXPLORER IV-1958 EPSILON ORBITAL DATA
SERIES, ISSUE 6. Army Ballistic Missile
Agency, Redstone Arsenal, Ala. Smithsonian
Institution, Astrophysical Observatory,
Cambridge, Mass. v. 1 of 6, Nov 1959.

The complete ephemeris for Explorer IV-1958 Epsilon is included in this volume and continued in volumes 2, 3, 4, and 5. The satellite-velocity vector is included. The magnetic-field vector is also tabulated, based on the most detailed description presently available for the magnetic field of the earth.

5. Augenstein, B.W.
DYNAMIC PROBLEMS ASSOCIATED WITH SATELLITE
ORBIT CONTROL. Lockheed Aircraft Corp.,
Missiles and Space Division, Palo Alto,
Calif. (Presented at the Aviation Confer-
ence of the American Society of Mechanical
Engineers, Los Angeles, Calif.) Paper 59-
AV-4, March 9-12, 1959.

The magnitudes of impulsive applications of force required to perturb the satellite orbit by desired amounts is calculated for some typical cases, under the assumption of a central force field. From these results, the case of continuously applied forces may be derived. The treatment is perfectly general and permits analysis of the effects of arbitrary initial

5. (cont'd) conical motion. For a few typical cases, the corresponding requirements of propellant consumption of chemical rockets is shown.

6. Arendt, P.R.
Anomalies of the geomagnetic retardation
of the spin of satellite Vanguard I (1958
BETA). ARS. J. v. 31, p. 286-289, 22 refs.,
Mar 1961.

Study of anomalies, indicated by continuous observations of the spin rate decay of satellite Vanguard I (Beta 1958), that do not fit into the picture developed from the theory of exponential magnetic damping by eddy currents.

7. Bandeen, W.R., Manager, W.P.
ANGULAR MOTION OF THE SPIN AXIS OF THE TIROS I
METEOROLOGICAL SATELLITE DUE TO MAGNETIC AND
GRAVITATIONAL TORQUES. National Aeronautics
and Space Administration, Washington, D.C.
Rept. TN-D-571, Apr 61.

The Tiros I spin axis exhibited an unexpected angular motion of as much as 3 to 5 deg per day, reaching a southernmost declination of -30 deg some 22 days after launch, then receding northward again. The effect is well explained by considering a primary torque due to interaction of a magnetic dipole along the spin axis with the Earth's magnetic field, and a secondary torque due to differential gravity in the Earth's gravitational field. An equation expressing the action of these torques was run on a computer, employing the initial orbital conditions, and the computed results agree closely with the observations. On May 27 a pair of spin-up rockets on the satellite was fired, increasing the angular velocity; greater stability of the spin axis has been noted subsequently.

8. Beard, D.B., Johnson, F.S.
Charge and magnetic field interaction with
satellites. JOURNAL OF GEOPHYSICAL RESEARCH,
Washington, D.C., v. 65, n. 1, p. 1-7, Jan 1960.

The interaction of a satellite with the magnetic field of the earth and the ionized medium through which it is moving has been investigated. Owing to the differing incident velocities of ions and electrons and therefore differing flux intensities, a negative potential will be induced on the satellite, but it is smaller than has previously been believed. Satellite motion across the magnetic lines of the earth will induce a voltage on the satellite of as much as 0.2 volt per meter of satellite size, and this may affect the interpretation of measurements of satellite potential. The magnetic drag resulting from the induced currents is proportional to the cube of the satellite dimensions and may exceed the mass drag for satellites larger than 50m in diameter; this can occur above 1200 km altitude, where the charge density exceeds the neutral density. Thus the magnetically induced current is an insignificant cause of drag. Although some useful power can be extracted from the induced current, it is not a very promising source of auxiliary power for presently conceived vehicles.

9. Beller, W.

Magnetic field to slow spacecraft. MISSILES

AND ROCKETS, v. 8, n. 8, p. 26-27, Feb 1961.

The use of a self-generated magnetic field is being proposed as a method of slowing down a spacecraft while it is in a low orbit or re-entering.

10. Blitzer, L.

THE ORBIT OF A SATELLITE IN THE GRAVITATIONAL

FIELD OF THE EARTH. Space Technology Labs.,

Inc. TR-60-0000-00264, 72p. August 1960.

A perturbation technique has been employed to calculate the orbit of a satellite, taking into account the effects of the second, third, and fourth harmonics in the potential function for the oblate earth.

11. Bryant, R. W.

THE EFFECT OF SOLAR RADIATION PRESSURE ON THE

MOTION OF AN ARTIFICIAL SATELLITE. National

Aeronautics and Space Administration. 8p. Sept. 1961.

(NASA TECHNICAL NOTE D-1063)

The effects of solar radiation pressure on the motion of an artificial satellite are obtained, including the effects of the intermittent acceleration which results from the eclipsing of the satellite by the earth. Vectorial methods have been utilized to obtain the nonlinear equations describing the motion and the method of Kryloff-Bogoliuboff has been applied in their solution.

12. Chapman, S.

REGULAR MOTIONS IN THE IONOSPHERE: ELECTRIC

AND MAGNETIC RELATIONSHIPS. High Altitude

Observatory, Boulder, Colo. 16p. incl. illus.

(Scientific rept. n. 35) 26 March 1960. (Contract

AF 19(604)-2140) (AFCLR-641).

Reprint from bull. of the AMERICAN METEOROLOGICAL

SOCIETY, v. 42, n. 85, p.100, Feb. 1961.

Regular worldwide motions in the ionosphere produce daily varying currents thereby dynamo action in association with the geomagnetic field. The changing field of these currents induces electric currents within the earth. At the earth's surface, the combined magnetic field of these currents is measured. The parts of primary and secondary origin can be determined separately. The form and intensity of the ionospheric currents can be found. Their height is inferred from the study of the ionospheric electron density and conductivity; it can also be measured by rockets. The daily varying airflow in the layer bearing the electric current, at heights from about 90 to 125 km, can to some extent be inferred. The motion is due partly to the sun's thermal and tidal action and partly to the moon's tidal action. Many aspects of the magnetic variations and the inferred ionospheric motions are considered in some detail, especially their seasonal and sunspot-cycle changes and their variations from day to day.

13. Chatterjee, J. S.

Magnetic disturbances and the earth's magnetic

field. JOURNAL OF GEOPHYSICAL RESEARCH, v. 66,

n. 5, p. 1535-1546, May 1961.

An attempt is made to explain the origin of the observed magnetic field of the Earth as a current system being maintained by world-wide magnetic disturbances.

14. Cohen, C. J., Frick, C. H., and Bressler, B. L.

EFFECTS OF MAGNUS FORCE ON AN EARTH SATELLITE.

U. S. Naval Proving Ground, Dahlgren, Va.

Technical Memorandum No. K-22/58, December 1958.

The magnitude of the Magnus force on a spherical satellite and the effect of this force on the orbit of the satellite are examined. The Magnus force was computed under the assumption that the free-stream flow impinges upon the body and becomes attached. It is shown that the Magnus force on a satellite (at a height of 100 miles and spinning at 180 rpm) is negligible when compared to the force of gravity, about 2×10^{-8} times the gravity force.

15. Conrath, B. J.

A HANDBOOK OF THE CELESTIAL MECHANICS OF

EARTH SATELLITES. Iowa, State University of,

Iowa City, August, 1959. SUI 59-31.

The motions of Earth satellites are affected by several factors. Those considered in this report are: deviations from the desired initial orbit due to deviations from desired initial conditions; perturbations due to atmospheric effects.

A brief discussion of the derivations required in each case is presented with the results summarized in a form which can be applied to specific cases.

16. DeBra, D. B.

THE EFFECT OF AERODYNAMIC FORCES ON SATELLITE

ATTITUDE (Presented at the Western Regional

Meeting, Stanford University, Palo Alto, Calif.

Lockheed Aircraft Corp., Missiles and Space

Division, Sunnyvale, Calif. American Astronautical

Society, Palo Alto, Calif. August 18-19, 1958.

58-32.

The effects of torques due to aerodynamic drag and the gravity gradient are computed for satellites orbiting between 80 and 375 mi altitude. Motion about the pitch axis is also discussed. The equilibrium position is determined as a function of altitude for both a dumbbell and a cylindrically-shaped object. The equilibrium position of the cylindrical object in three dimensions is discussed as a function of altitude. Equations are presented in an appendix.

17. Debrunner, H., and Houtermans, F. G.
CORRELATION BETWEEN FORBUSH DECREASES OF
COSMIC RADIATION AND SATELLITE DRAG. (Bern
Universitat, Switz.). Space Research. First
International Space Science Symposium, Proc.,
Hilde Kallmann Bijl, ed. p. 37-45, 1960.

Data published by Jacchia on the secular acceleration of artificial earth satellites are compared with Forbush decreases in cosmic radiation intensity recorded over the same period by means of double Simpson-type neutron monitor piles. A strong correlation is shown between these cosmic-ray intensity variations and the drag on satellites. The Forbush decreases (known to correlate strongly with sun spot activity, terrestrially observed magnetic storms and the intensity of radio-noise bursts from the sun) seem to be caused by an additional shielding of interstellar cosmic radiation due to magnetic changes in the two Van Allen radiation belts. The additional satellite drag probably is due to an increase of the altitude of a given gas density level resulting from the additional heating of the upper atmosphere by corpuscular radiation emitted from the sun, following solar magnetic disturbances.

18. De Orus, J. J.
ON THE APPARENT MOTION OF AN EARTH'S ARTIFICIAL
SATELLITE (Presented at the Tenth Annual Congress
of the International Astronautical Federation,
London, August 30-September 5, 1959. Spain,
Fabra Observatory, Barcelona.

It is pointed out that a primary problem in radio observations of an artificial satellite is determining the time when the satellite is at its minimum distance from a determined Earth station. This time calculation is simplified owing to the feeble flattening of the terrestrial globe and the slight relation between the periods of revolution of the satellite and the Earth's rotation.

19. DiTaranto, R. A., and Lamb, J. J.

The space environment - A preliminary study.

ELECTRICAL MANUFACTURING, v. 62, n. 4,

(Acc. n. 14671) Oct 1958.

Analysis of natural environments in space (above 75,000 feet) as they affect future equipment design. Anticipated values are established for atmospheric composition, pressure, solar radiation, ozone, dissociated gases, aurorae, ionized gases, solid particles, and the earth's magnetic field.

20. Dolginov, S. Sh., and Pushkov, N. V.

SOME USSR RESULTS OBTAINED BY MEASURING THE

MAGNETIC FIELD OF THE EARTH WITH A SPACE

ROCKET. (Doklady Akademii Nauk, SSSR, v. 139,

n. 1, November/December 1959). U. S. Dept. of

Commerce, Washington, D. C., Office of Technical

Services, OTS: 60-31,013, U. S. Joint Publications

Research Service, New York, N. Y., JPRS:L-1981-D.

The data of the magnetic measurements obtained with a space rocket indicate the usefulness of the theories allowing the emergency of external sources of the magnetic field at distances of several radii from the center of the Earth.

21. Doolin, B. F.

GRAVITY TORQUE ON AN ORBITING VEHICLE.

National Aeronautics and Space Administration,

Ames Research, Moffett Field, Calif. 1959. NASA TND-70.

The potential energy of a small body moving under the influence of only the earth's gravity field is derived. It is shown that the effects of the earth and body oblateness are separate to terms of second order in the potential energy function. The invariance of the potential energy under orthogonal transformations is discussed and is used to simplify calculations of the terms in the potential function. The equations of the motion of the vehicle are obtained in generalized, and in body coordinates. The components of torque in body coordinates are obtained by a transformation determined by the invariance of rotational power. Two applications of the equations of motion in body coordinates are made. First it is shown that an energy integral does not exist for these equations since they are derived with respect to the satellite mass center. Then the equations are applied in simplified form to an examination of the stability of a vehicle in a circular orbit.

22. Doolin, B. F., and Triplett, W. C.
 THE INFLUENCE OF GRAVITY ON THE MOTION OF AN
 EARTH SATELLITE. National Aeronautics and
 Space Administration, Ames Research Center,
 Moffett Field, Calif. (Presented at the 6th
 National Annual Meeting of the American
 Astronautical Society, January 18-21, 1960,
 N. Y.) Preprint n. 60-34.

This paper contains some results of a study of the effect of gravity torque on the angular motion of a near-Earth satellite. To be sure, gravity is not the only source of disturbance for the vehicle; however, since for many year missions, satellites will be required either to point towards the Earth or to hold a fixed heading for extended periods of time, it is of interest to know to what extent the gravity torque can be used for orientation control or reference, or how much power should be available to overcome it.

23. Ellis, G. A., and Diana, A. C.
 MOTION OF A SATELLITE ABOUT THE EARTH-MOON
 SEXTILE POINTS. RCLS TM-60-1, 18p. September 1960.

The motion of a selenoid in the neighborhood of the sextile point under the simultaneous influence of the gravitational fields of the earth and moon has been investigated.

24. Ellis, G. R. A.
 Geomagnetic micropulsations.
 AUSTRALIAN JOURNAL OF PHYSICS.
 v. 13, n. 4, pp. 625-632, Dec 1960.

This paper presents the results of a series of observations over a range of geomagnetic latitudes extending from 28 to 51 deg S for the period of September 1959 to April 1960. It is shown that there is no observable change in the micropulsation period with latitude, although there is a monotonic increase in the amplitude for all periods between 10 and 100 sec. The interpretation of these results in terms of existing theories is discussed.

25. Fain, W. W., and Greer, B. J.
 Electrically charged bodies moving in the
 earth's magnetic field. ARS J., v. 29,
 n. 6, p. 451-453, Jun 1959.

An investigation was initiated to determine the effect on the path of electrically charged bodies moving in the Earth's magnetic field. The study is applicable to: 1) Perturbation in satellite orbits (charging the satellite can be used to afford a small measure of control over the orbit). 2) The effect on the path of a rocket fired from the Earth. 3) The effect on charged particles entering the Earth's magnetic field.

26. Freed, L. E.
 ATTITUDE CONTROL SYSTEM FOR A SPINNING BODY
 (Presented at the National IAS/ARS Joint
 Meeting, Los Angeles, Calif., June 13-16,
 1961). (Space Technology Laboratories, Inc.,
 Los Angeles, Calif.) American Rocket Society,
 Inc., New York, N Y. 61-207-1901.

An attitude control system for a spinning body that is capable of accurately stabilizing the attitude of the spin axis under the influence of load torque impulses is presented. The transient response and steady-state behavior of

the system under various torque loading conditions are analyzed. A comparison is made between the performance obtained with the spinning body control system for a nonspinning body. The analysis is carried out in terms of coordinates that are complex functions of time. Some mathematical simplification results from this procedure. The spinning-body attitude-control system, under the constraints of the assumptions made, is shown to be capable of performance to that of a nonspinning-body control system. However, the spinning-body control system is generally more difficult to mechanize.

27. Frye, W. E., and Stearns, E. V. B.
 Stabilization and attitude control of satellite
 vehicles. ARS J., v. 29, n. 12, p. 927-930,
 Dec 1959.

The status of concepts and techniques in the field of satellite attitude control and stabilization as reflected in the open literature of the last five years is reviewed. Stabilization by means of the gravity gradient, aerodynamic torques and radiation pressure is examined. Various attitude sensors and torque generators are discussed. The sources of distributing torques are briefly summarized.

28. Garfinkel, B.
 ON THE MOTION OF A SATELLITE OF AN OBLATE
 PLANET. Aberdeen Proving Ground, Md.,
 Ballistic Research Laboratories, Report N. 1018,
 July 1957.

An approximate orbit is here defined by the potential function

$$V_0 = -\mu/r - 3k (\sin^2\theta - \cos^2i) / a(1 - e^2) r^2$$

with

$$\mu = 1 - 3k' [1 - 3/2 \sin^2i] / a^2(1 - e^2)^{3/2}$$

where r is the radius vector, θ is the complement of the polar angle, a , e , and i are constants analogous to the usual elliptic elements, and k is the equatorial bulge constant. The choice of V_0 leads to a simple closed solution, free from all secular perturbations. The longitude is affected by a long-period perturbation of amplitude

$$3e^2 \sqrt{1 - e^2} \sin^2 i / 16 [1 - 5/4 \sin^2 i]$$

which must be applied as an orbit correction of the value of the inclination is in the neighborhood of the resonance value $63^{\circ}.4$. The remaining perturbations in stations are planned for the Arctic. These stations must be shielded from civilization by terrain. The reason for this is the necessity of maintaining an extremely low ambient noise level in the vicinity of the station. In this report the facilities necessary for successful operation of these stations are outlined.

29. Gedeon, G. S.

ORBITAL MECHANICS OF SATELLITES (Presented at the Western Regional Meeting, Stanford University, Palo Alto, Calif., August 18-19, 1958). Chance Vought Aircraft, Inc., Dallas, Texas American Astronautical Society, Palo Alto, Calif. 58-19.

The problem associated with placing a satellite into a particular orbit, either from a boost trajectory, or from another orbit, can be solved by well-known equations. However, the solutions are often cumbersome due to the transcendental nature of the equations. In this paper a set of explicit relations is presented, which permits the direct solution of the problem of either determining the orbit from a given set of initial conditions, or of determining the initial conditions required to obtain a given orbit. These relations are presented on charts for convenience. Also treated is the problem of transfer between elliptic orbits which do not intersect. The treatment is a generalization of the Hohman transfer ellipse problem in the sense that the initial and final conditions are not concentric circles, but rather, confocal ellipses with skewed axes. The numerical examples, which were obtained with high-speed digital computers, show that the orbiting target can be intercepted only if the interceptor and the target are in proper juxtaposition. The conditions for proper juxtaposition are discussed.

30. Geyling, F. T.

Fundamental satellite perturbations. ARS J., v. 30, n. 11, p. 1009-1012, Nov. 1960.

A brief exposition, from an elementary point of view, is given for some basic satellite perturbations. The treatment serves to generate independent checks of formal results from more elaborate analyses and to establish a direct relation of these results to physical principles. Attention is given to in-plane and precessional perturbations of circular orbits resulting from oblateness, luni-solar gravitation and radiation pressure. The derivations have quantitative validity and may be extended to more general situations.

31. Geyling, F. T.
Satellite perturbations from extraterrestrial gravitation and radiation pressure. FRANKLIN INSTITUTE, JOURNAL v. 269, n. 5, p. 375-407, May 1960.

The equations of motion of a satellite are written in terms of displacement components relative to the unperturbed, elliptic orbit. A moving system of coordinates is used which consists of an orthogonal triad whose origin is always located at the nominal satellite position on the elliptic orbit.

32. Graham, E. W., and Beane, B. J.
OPTIMUM TRAJECTORIES WITH ATMOSPHERIC RESISTANCE
Douglas Aircraft Corp., Santa Monica Div. Report
n. SM-23745, November 1959.

Problem involving the transfer of a rocket vehicle from one point to another with minimum fuel expenditure are considered. The transfer time and the terminal velocity vectors are specified.

The first problem studied is one in which atmospheric resistance is the only external force acting on the vehicle. In the second problem both atmospheric resistance and centrally directed gravitational forces are included. (The case in which centrally directed gravitational forces are the only forces appearing has been considered previously).

In all cases there is employed a translating but non-rotating coordinate system whose origin follows a coasting trajectory between the terminal points. The linearized perturbation force field in this coordinate system is used. Two different methods are employed. One is a method of bounds which yields information which is general, but not complete or precise. In the second method the equations of motion in the moving coordinate system are used and the results are more precise but not so simple and general in their application.

The methods are by no means intended to replace the methods of variational calculus, but should supplement them and perhaps provide a somewhat different viewpoint for examining such problems. Some attempt has been made also to obtain a physical understanding of the factors which determine the desirability of using intermediate impulses in some cases while terminal impulses alone are optimum in other cases.

33. Grasshoff, L. H.

A method for controlling the attitude of a spin-stabilized satellite. ARS J., v. 31, p. 646-649, May 1961.

Presentation of a method for applying controlled torque to a satellite spin axis. A current-carrying coil is placed around or on the satellite, such that the magnetic axis of the coil is parallel to the spin axis. By appropriate switching of the coil current, torques may be generated which average zero about our transverse axis but have a net value about the other transverse axis. The required ground computational program is outlined, and a possible system configuration for spin-axis attitude control is proposed.

34. Grasshoff, L. H.

Eddy current torque compensation in a spin stabilized earth satellite. ARS J., v. 31, p. 290-293, Mar 1961.

Analysis demonstrating the feasibility of compensating for eddy current torque by electromagnetic means. The vector torque produced by eddy currents in a conducting body rotating in the earth's magnetic field bears a unique relation to the spin vector and the field vector. A simple coil arrangement is discussed which produces a vector torque and effectively cancels the eddy current torque, thus eliminating the spin decay and precession due to induced eddy currents.

35. Grazley, C. Jr., Kellogg, W. W., and Vestine, E. H.

SPACE VEHICLE ENVIRONMENT. Rand Corp., Report P-1335, (Rev.), 58p. (t13 R15r Contin.) June 1959.

Effects of solar and other thermal radiations on vehicle temperature, the characteristics of the Earth's magnetic fields and other magnetic fields in space, the Earth's exosphere and the solar corona, cosmic rays, and meteoroids.

36. Hewitt, M. H.

Angular displacement of a magnetized sphere by the terrestrial magnetic field during vertical descent.

ARS J., v. 30, n. 6, p. 558, Jun 1960.

The angular displacement bounds of a sphere with a magnetic dipole field are given for free-fall vertical descent in Earth's gravitational and magnetic fields. Effects of the atmosphere are neglected, and Earth is assumed spherical. The terrestrial magnetic field is treated as the field from a dipole situated at Earth's center.

37. Hibbard, R. R.

Attitude stabilization using focused radiation

pressure. ARS J., v. 31, p. 844 Jun 1961.

Discussion of a space vehicle attitude stabilization system using focused solar radiation pressure. The radiation pressure forces are studied and the magnitude of the correcting torques is analyzed.

38. Holl, H. B.

THE EFFECT OF RADIATION FORCE ON SATELLITES OF

CONVEX SHAPE. National Aeronautics and Space

Administration, Wash., D. C. TN D-604.

These studies were made for application to computations of both a satellite's attitude and trajectory, which are to take into account the effects of the radiation pressure. The radiation force acting on a body is a function of certain physical properties, of which the reflectivity of the bodies surface is the most important. The force F can be expressed in the form: $F = p_0 \times A \times C_f$. A means the projected area of the body, and p_0 is the radiation pressure in the vicinity of the Earth. The function C_f was introduced in analogy to the aerodynamic expressions for the drag, and may be called the "radiation force coefficient". The purpose of this report was to derive accurate formulas and limits for the radiation force coefficient for certain convex bodies. For infinit bodies, the result is that C_f is limited by; $0 < C_f \leq 2$.

39. Ives, N. E.
 THE EFFECT OF SOLAR RADIATION PRESSURE ON THE
 ATTITUDE CONTROL OF AN ARTIFICIAL EARTH
 SATELLITE. Royal Aircraft Establishment
 (GT. BRIT.) AD-260 652, (Tech. note n. GW-570)
 April 1961.

An account is presented of the demand made by solar radiation pressure on the attitude control system of an Earth satellite whose external configuration is in the shape of a rectangular prism, the surfaces being assumed to be perfectly reflecting. Expressions determining the amount of angular impulse that must be supplied by an attitude control system in the course of a year in order to provide perfect stabilization for a space-stabilized satellite, and an Earth-pointing satellite in a non-precessing orbit, are developed. Examples are given for particular cases and further examples include a comparison of the radiation pressure torque with the torque set up by the Earth's gravitational field, and the attitude deviations arising as a result of radiation pressure on an Earth-pointing satellite employing gravity gradient stabilization alone.

40. Ives, N. E.
 PRINCIPLES OF ATTITUDE CONTROL OF ARTIFICIAL
 SATELLITES. Great Britain, Royal Aircraft
 Establishment, Farnborough. TN G.W. 534,
 November 1959.

The equations of attitude motion are derived for small angular displacements from the equilibrium position of an Earth-pointing satellite employing reaction flywheel damping. This is followed by a discussion on the attitude control of a space-stabilized satellite, with particular reference to attitude control against the gravitational torque due to the Earth and the use of reaction-jets for the control of a spherical satellite configuration; finally, a single plane analytical account is given of a method of eliminating any undesirable angular momentum which the satellite may possess immediately as it leaves the carrier missile for its future orbit.

41. Jacchia, L. G.
 Corpuscular radiation and the acceleration of

artificial satellites. NATURE (LONDON)

v. 183, p. 1662-3, Jun 1959.

The orbital accelerations of satellites 1958 2 and 1958 1 show a close correlation with 10.7 cm solar radio flux. Two distinct irregularities in the curve for 1958 1 coincide with the only great geomagnetic disturbances occurring in the lifetime of the object. It is suggested that these irregularities are due to the effect of a solar corpuscular stream on the atmospheric density at a height of 200 km.

42. Jefimenko, O.

Effect of the Earth's magnetic field on the motion of an artificial satellite. AMER.

J. PHYS., v. 27, n. 5, p. 344-8, May 1959.

The effect when moving in a circular orbit in the plane of the magnetic equator of the earth is discussed. Approximate formulae for the current induced in the satellite and for the resulting induction drag are obtained. The current in a conducting satellite of an average size at an altitude of several hundred kilometers is estimated to be of the order of milliamperes. The induction drag may exceed the friction drag for satellites of large dimensions and for elongated satellites.

43. Kamm, L. J.

Magnetorquer- a satellite orientation device.

ARS J., v. 31, p. 813-815, Jun 1961.

Analysis of an attitude control motor which generates a torque by the action of the earth's magnetic field on electric currents in the satellite. Components of the system are a magnetometer to measure the earth's field, a set of coils to carry the current, and a computer. The generation of the torque is studied.

44. Kapus, T. E.

SATELLITE VEHICLE NATURAL RESTORING TORQUES.

(NAA-SR-Memo-4615) (Atomics International. Div. of North America Aviation, Inc., Canoga Park, Calif.)

p. 23, November 1959.

The natural restoring torques on a satellite vehicle are analyzed with a 3-dumbbell configuration approach. The results are applied to the case of a rectangular parallelepiped with a density of 3 lb/ft^3 .

45. King-Hele, D. G.
 Perturbations of the orbit of a satellite near
 to the Earth. ROYAL SOCIETY, PROCEEDINGS
 v. 248, s. A, p. 55-62, Oct. 1958.

The main perturbations of a satellite orbit near the earth are those caused by the earth's oblateness and the atmosphere. Fortunately these two sources produce perturbations of quite different types, and as a first approximation they can be treated separately, though the cross-couplings would have to be evaluated in a thorough analysis of the subject.

46. Krafft, A. E.
 SPACE FLIGHT. I ENVIRONMENT AND CELESTIAL
 MECHANICS. VI. 513 pp. D. Von Nostrand Co.,
 Inc., Princeton, N. J. (UG 630 M55p), 1960.

Utility of space flight, the solar system, the central force field, the orbit in space, and perturbations are discussed.

47. Krause, H. G. L.
 THE SECULAR AND PERIODIC PERTURBATIONS OF THE
 ORBIT OF AN ARTIFICIAL EARTH SATELLITE.
 Army Ballistic Missile Agency, Redstone Arsenal,
 Huntsville, Ala. September 1956.

The motion of an earth satellite in an orbit to the earth's equator is investigated. Secular perturbations of this orbit caused by the oblateness of the earth and by the sun and moon and periodic perturbations caused by the atmosphere of the earth are analyzed. For a selected orbit of a earth satellite, it is shown numerically which secular and periodic perturbations are the most important. Furthermore, for a nonstationary orbit, where the atmospheric resistance has still relatively great influence, an analytic formula is developed for the computation of the lifetime of the satellite. Numerical values for this lifetime are in fairly good agreement with other estimates.

48. Lass, H., and Lorell, J.
 SATELLITE MOTION ABOUT AN UNSYMMETRICAL
 BODY. Jet Propulsion Laboratory, California
 Institute of Technology, Pasadena, External
 Publication 646, May 1959.

The motion of a satellite is obtained in explicit closed form by applying the nonlinear technique of Kryloff-Bogoliuboff. It is shown that if a perturbing mass is close to the principal center of force, the motion of the satellite remains essentially elliptic.

49. Leeper, E.
 ATMOSPHERIC PERTURBATIONS OF ARTIFICIAL
 SATELLITES. RAND Corp., Santa Monica,
 Calif. P-1496, September 1958.

The purpose of this paper is to present straightforward and accurate methods of computing drag perturbations, with corrections for influencing factors such as the rotation of the earth. Preliminary considerations and basic ideas as well as the mathematical formulas are given for this type of computation.

50. Levin, E.
 SATELLITE PERTURBATIONS RESULTING FROM LUNAR
 AND SOLAR GRAVITATIONAL EFFECTS. RAND Corp.,
 Santa Monica, Calif. P-1561, December 1958.

The perturbations of a near-circular earth satellite orbit by the gravitational attraction of the sun or the moon may be determined by using relatively simple mathematical techniques. The results are in agreement with those obtained by more elaborate and somewhat less familiar methods used in celestial mechanics.

51. Lundquist, C. A.
- EQUATIONS OF MOTION OF SATELLITE IN
 UPPER REGION OF THE EARTH'S ATMOSPHERE
- Ordnance Missile Laboratories, Army
 Rocket and Guided Missile Agency, Redstone
 Arsenal, Ala. Report 6M64 (ASTIA AD-105,883)
- April 1955.

The equations of motion of a satellite under the influence of the gravitational field of the earth and a drag force due to air resistance are formulated. Effect of the rotation of the atmosphere is discussed.

52. Malinina, N. Ye.
- THE EARTH'S MAGNETIC FIELD
- U.S. Department of Commerce, Office of
 Technical Services, Washington, D. C.
- August 1960.

This lecture is divided into the following topics: The Elements of Terrestrial Magnetism, Magnetic Surveys, Secular Variations, Graphic Presentation of the Earth's Magnetic Field, The Structure of the Earth's Magnetic Field and Magnetic Anomalies, Hypotheses Concerning the Origin of the Earth's Permanent Magnetic Field, Component Parts of the Earth's Variable Magnetic Field, Magnetic Activity, Solar Diurnal Geomagnetic Variations, and Magnetic Storms.

53. Mark, H., and Ostrach, S.
- The inflated satellite - Characteristics in
 sunlight and darkness. Appendix I - Radiation
 pressure. Appendix II - Conservation of
 energy equation and equilibrium temperature
 calculations. Appendix III - Time required

for equilibrium conditions to be established. Appendix IV - Sphere deflection and buckling due to the net external pressure. Appendix V - Heat-sink temperature.

AEROSPACE ENG., v. 20, p. 10, 11, 30-38,
Apr 1961.

Discussion of the deformation forces acting on an inflated plastic satellite in orbit at 1,000 mi. altitude. The two most important forces are found to be stagnation pressure and radiation pressure. It is concluded that a 0.5-mil thick Mylar satellite 100 ft. in diameter, inflated with anthraquinone, will retain its shape during the entire course of such an orbit. The internal pressure is necessary only to inflate the sphere, and plays no important role in keeping it inflated. Under other conditions, however, the satellite shape and performance will be affected by its internal pressure. One method of obviating the problem caused by large temperature variation is the utilization of the heat capacity of the subliming solid. Calculations indicate the possibility of using a solid with a high vapor pressure to provide an excess of internal pressure, and yet stay within the bounds of the bursting limits.

54. Muhleman, D. O., et. al.
OBSERVED SOLAR PRESSURE PERTURBATIONS
OF ECHO I. Jet Propulsion Laboratory,
California Institute of Technology,
Pasadena, TR 34-114, August 1960.

During the period August 13 to 22, 1960, day-to-day determinations of the average orbital elements of the 100-ft Echo I balloon, based on observations taken at the Jet Propulsion Laboratory's Goldstone tracking station, indicated a decrease in perigee height of 3.0 km/day and an increase in the eccentricity of 0.00038/day.

55. Musen, P., Bailie, A., and Upton, E.
 DEVELOPMENT OF THE LUNAR AND SOLAR
 PERTURBATIONS IN THE MOTION OF AN
 ARTIFICIAL SATELLITE. U. S., NASA
 TN D-494. p. 44, January 1961.

Analysis of the problems relating to the influence of lunar and solar perturbations on the motion of artificial satellites by means of an extension of Cayley's development of the perturbative function in the lunar theory. The results are modified for incorporation into the Hansen-type theory used by the NASA Space Computing Center. The theory is applied to the orbits of the Vanguard I and Explorer VI satellites, and the results of detailed computations for these satellites are given together with a physical description of the perturbations in terms of resonance effects.

56. Musen, P.
 A MODIFIED HANSEN'S THEORY AS APPLIED
 TO THE MOTION OF ARTIFICIAL SATELLITES.
 National Aeronautics and Space Administra-
 tion, Washington, D. C. TN D-492.
 November 1960.

This report presents a theory of oblateness perturbations of the orbits of artificial satellites based on Hansen's theory, with modification for adaptation to fast machine computation. The theory permits the easy inclusion of any gravitational terms and is suitable for the deduction of geophysical and geodetic data from orbit observations on artificial satellites. The computations can be carried out to any desired order compatible with the accuracy of the geodetic parameters.

57. Musen, P.
 On the long-period lunisolar effect in the
 motion of the artificial satellite. JOURNAL
 OF GEOPHYSICAL RESEARCH, v. 66, n. 6, p. 1659-1665,
 Jun 1961.

Two formulas are presented for the determination of lunar and solar long-period effects of the first order in the motion of an artificial satellite.

58.

Musen, P.

ON THE LONG PERIOD LUNI-SOLAR EFFECT IN

THE MOTION OF AN ARTIFICIAL SATELLITE. U.S.

NASA TN D-1041, p. 21, July 1961.

Presentation of formulas for determining the long-period perturbations caused by the sun and the moon in the motion of a satellite. The basic equations of the two systems presented are arranged in a form permitting the use of numerical integration, and are both more accurate and more adaptable to electronic computation than previous formulas.

59.

National Academy of Sciences

Effects of a severe solar storm on the

orbit of ECHO 1. IGY BULLETIN n. 44,

pp. 6-7, Feb. 1960.

Reasons for the solar activity of November 12, 1960 affecting the orbit of Echo 1 are explored.

60.

Newell, H. E., Jr.

SATELLITES AND SPACE PROBES. National

Aeronautics and Space Administration,

Washington, D. C. Space Science Lecture

n. 4, NASA 59-109, March 1959.

A fundamental explanation of the mechanics of space trajectories is presented. The relationships of mass, speed, gravity, etc., employed in calculating these trajectories are explained.

61. Newton, R. R.
Method of stabilizing an astronomical
satellite. ARS J., v. 29, p. 665-666,
Sept 1959.

In the operation of a satellite being used for astronomical observations, it is clearly advantageous for the satellite to have zero angular momentum with respect to the fixed stars. However, this condition, even if achieved at some epoch, cannot be maintained indefinitely; there are always small torques arising from meteorite impacts, gravitation, and radiation pressure, acting to alter the angular momentum. A system is suggested which unbalances, in a controlled way, the mass distribution of a satellite and thus produces gravitational torques on the satellite.

62. Newton, R. R.
Stabilizing a spherical satellite by
radiation pressure. ARS J. v. 30,
p. 1175-1177, Dec 1960.

Navy-supported analysis considering the torque caused by radiation pressure on three different configuration of a spherical satellite. It is concluded that the radiation pressure is adequate to overcome the destabilizing gravitational torque, if reasonable care is used in the mass balance of the satellite.

63. Nonweiler, T.
Effect of solar flares on earth satellite
1957 B NATURE (LONDON) v. 182, p. 469-9,
Aug 1958.

An apparent correlation appears if the rate of decrease of the period of the earth satellite 1957 B, and the concurrent variation in the total intensity of major solar flares, are compared. The sense of the correlation implies that world-wide decreases of ionospheric air temperature, or of air density, or both, result from the flare activity.

64. Oberth, H.
 A PRECISE ATTITUDE CONTROL FOR ARTIFICIAL
 SATELLITES. Army Ballistic Missile Agency,
 Huntsville, Ala. Apr 1957.

An attitude control for artificial satellites is described. This control utilizes the "tidal forces" which are exerted upon the satellite. The great advantage in using this method of control is its precision. An accuracy of 0.0001 radian (21 sec) can be realized without difficulty. A disadvantage of this system is that it cannot be used alone. It must be complemented with some other means of control to bring the satellite to a desired attitude from which it can be further controlled by the method described herein. "Tidal forces" are defined, described, and calculated. Several technical proposals are given concerning their use for an attitude control.

65. Petersen, N. V.
 Lifetimes of satellites in near-circular and
 elliptic orbits. ARS J., v. 26, n. 5, p. 341-351,
 368.

The problem of determining the approximate lifetime or duration for simple satellite configurations as influenced by the gravitational field and atmospheric envelope of the earth is considered. The equations of motion for the case of initial near-circular and elliptic orbits for spherical and conical body shapes exposed to the rarefied atmosphere are shown. An approximate solution for the differential equations of motion is presented for the special case of diffuse reflection for free molecule flow. Lifetimes for small instrumented satellites having a mass-area ratio of 1 slug/ft², satellite bodies having extremely small mass-area ratios of 0.1 slug/ft², and for large vehicles having mass-area ratios of about 10 slugs/ft² are shown. The lifetimes of satellites increases markedly with altitude and mass-area ratio.

66. Pushkov, N. V., and Dolginov, S. S.
 STUDY OF THE GEOMAGNETIC FIELD FROM ARTIFICIAL
 SATELLITES AND ROCKETS. Uspekhi Fizicheskikh
 Nauk: v. 63, n. 4, pp. 645-656, Hope, E. R.,
 translation. Directorate of Scientific

Information Service, Defence Research

Board, Canada, T 276R, 1957.

In this paper some of the geophysical and technical aspects of geomagnetic measurements from satellites are reviewed. The problems encountered are discussed. Possibilities of future uses of satellites in this field are presented and magnetometers suitable for such work are described.

67. Reiffel, L.

Structural damage and other effects of

solar plasmas, ARS J., pp. 258-262, Mar 1960.

For orbits or trajectories that carry large area lightweight structures outside of protected regions of space defined by planetary magnetic fields, the damaging effects of solar-plasma streams are shown to be potentially serious and may result in low durability or high payload penalties. Estimates given depend directly on plasma-stream densities and velocities which are only very approximately known.

68. Roberson, R. E.

ATTITUDE CONTROL OF A SATELLITE VEHICLE --

AN OUTLINE OF THE PROBLEMS. Autonetics

Division of North American Aviation, Inc.,

Downey, Calif. American Rocket Society,

New York 36, New York. Paper 485-57, October 1957.

The attitude of a satellite vehicle must be controlled for many applications. This paper describes some of the fundamental problems associated with the design of an attitude control system. These include the choice of an attitude reference system and of reference axes within the body, and the nature of the attitude perturbation torques acting on the satellite. Attitude equations of motion are derived and a rationale for a control system synthesis is suggested. Control torque sources, the effects of vehicle configuration, and the role of attitude sensing devices are discussed.

69. Roberson, R. E.
A unified analytical description of satellite
attitude motions. *ASTRONICA ACTA* (In
French), v. 5, n. 6, pp. 347-355, 1959.

Previous formulations of the equations of satellite attitude motion and the perturbation torques on the satellite are unified and generalized.

70. Roberson, R. E.
A unified analytical description of satellite
attitude motions. *ASTRONICA ACTA*, v. 5, n. 6,
p. 347-355, 1959.

Previous Formulations of the equations of satellite attitude motion and the perturbation torques on the satellite are unified and generalized. Equations of motion are developed in terms of arbitrarily large attitude deviation angles relative to an arbitrary attitude reference frame. Explicit expressions are obtained for effective external and parametric excitation torques from internal moving parts, inertial reaction control parts, and the motion of the attitude reference frame.

71. Rowell, L. N., and Smith, M. C.
Effect of geometrical libration on the
damped motion of an earth satellite. *ARS J.*,
v. 31, p. 361-364, Mar 1961.

Study of the effect of geometrical libration on the damped motion of a satellite about its pitch axis. Several stabilizing systems are discussed. It is shown that a combination of sensing devices will effectively remove the found error in pitch which is caused by geometrical libration. This is achieved by accurate tuning and not by depending on orbits having extremely small eccentricities, as in the case when the horizon sensor or gyro sensor is used separately.

72. Savet, P.H.
Satellite attitude-detection and
control. ARMA ENGINEERING v. 3,
n. 4, p. 4-9, Nov 1960.

The problem of nonuniform gravitational fields is reviewed with respect to satellite control, and the possible application of gradient techniques thereto is discussed.

73. Schlegel, R.
Radiation pressure on a rapidly moving
vehicle. AMERICAN JOURNAL OF PHYSICS
v. 28, n. 8, p. 687-694, Nov 1960.

The radiation pressure is calculated for a surface which is moving in an electromagnetic radiation field that is isotropic to rest observer.

74. Science and Tech. Section, Air Force
Information Div., Washington, D.C.
PHENOMENA IN THE UPPER ATMOSPHERE REVIEW
OF SOVIET LITERATURE. Monthly rept. no.
14, June 61.

Material are reported on the following topics: (1) Ionospheric electron concentration, (2) Solar radiation and the ionosphere, (3) Van Allen belts and cosmic rays, (4) Telluric currents, (5) Atmospheric electricity, and (6) Satellite and missile data.

75. Shapiro, I.I. and Jones, H.M.
Perturbations of the orbit of the
echo balloon. SCIENCE v. 132, p. 1484-86,
18 Nov 1960.

76. Singer, S.F.
 MEASUREMENT OF THE ELECTRIC CHANGE OF
 A SATELLITE. Physics*Department, Univ.
 of Maryland, College Park. Final rept.
 on Grant NSF/IGY-32.2/216, 31 Mar 59.

A literature survey was undertaken to ascertain the best values for the environmental parameters in a satellite orbit. These parameters include the gas temperature, the average velocities of ions and electrons and their respective temperatures, the gas density, and the degree of ionization. From these data, an estimate of the electrostatic potential of a satellite is determined. Photo-emission of electrons from the satellite skin is the primary investigation undertaken in this report. The hot-probe technique is given careful consideration, and the components for such a probe are described.

77. Smithsonian Institution, Astrophysical
 Observatory, Cambridge, Massachusetts.
 RESEARCH IN SPACE SCIENCE. Special rept.
 56, 30 Jan 61.

This report contains the following papers: "A Method of Analysis for Lens and Mirror Systems" by R.J. David, S.E. Strom, and K.M. Strom; "A Determination of the Ellipticity of the Earth's Equator From the Motion of Two Satellites" by I.G. Izsak; "Effects of Solar Radiation Pressure on the Motion of an Artificial Satellite" by Y. Kozai.

78. Sohn, R.L.
 Attitude stabilization by means of solar
 radiation pressure. ARS JOURNAL v. 29,
 n. 5, p. 371-73, May 1959.

This paper demonstrates the feasibility of stabilizing the attitude of a space vehicle by means of solar radiation pressure. If a suitable weathervane-type trail surface is attached to the vehicle, solar radiation pressure, acting on the weathervane, will stabilize the vehicle against disturbing torques which arise from gravitational eccentricities (dumbbell effect), meteorite impacts and solar radiation pressure.

79. Stocker, T.A.J., and Vachino, R.F.
 THE TWO-DIMENSIONAL LIBRATIONS OF A DUMB-
 BELL SHAPED SATELLITE IN A UNIFORM GRAVITA-
 TIONAL FIELD. Wright Air Development
 Center, Wright-Patterson AFB, Ohio;
 American Astronautical Society, Palo Alto,
 Calif. (Presented at the Western Regional
 Meeting, Stanford University, Palo Alto,
 Calif., 18-19 Aug 1958)

Many proposed applications of artificial Earth satellites require that the satellites be oriented relative to the direction of the Earth, the local vertical. It has been proposed that a satellite in the shape of a dumbbell inherently senses the direction of the vertical. The motion of such a dumbbell has been studied by first deriving the equation of motion of a point-mass satellite in a central force field--the classical two-body system--and then by extending the analysis to the modified three-body system which the dumbbell presents. The three equations of motion of the dumbbell are derived using Newton's law and are then simplified by a series of approximations in order to compare the attitude and orbital motion of the dumbbell with the motion of the dumbbell with the motion of a point-mass satellite. The complete equations of motion of the dumbbell are programmed on a digital computer for various initial orbital and dumbbell attitude conditions and for different dumbbell lengths. The results show that only in a circular orbit can the dumbbell ever be permanently aligned along the local vertical, and that for elliptical orbits of small eccentricity the dumbbell performs undamped sinusoidal oscillations of varying amplitude and frequency. In elliptical orbits of high eccentricity the dumbbell rotates almost continuously. The dumbbell length and its attitude motion do not perturb its orbit.

80. Struble, R.A.
 The geometry of the orbits of artificial
 satellites. ARCHIVE FOR RATIONAL MECHANICS
 AND ANALYSIS v. 7, n. 2, p. 87-104, Feb 1961.

An approach to the study of the orbits of artificial satellites is presented. The basic geometry and other aspects of satellite motion which are of importance to satellite engineering are emphasized. The motion of the orbital

80. (cont'd) plane as a rigid body is introduced and a nonelliptical orbit motion in this plane is defined.

81. Tandon, J.N.
Oscillations of rotating cosmical bodies
in the presence of magnetic field. INDIAN
J. PHYS. v. 34, n. 3, p. 107-17, Mar 1960.

The effect of rotation on the radial pulsations of cosmical fluid masses with special reference to spherical mass (magnetic variables) and cylindrical mass (spiral arm, solar-ion stream) was investigated when the fluids have volume electric currents. Two models of current systems are considered for cylindrical mass: circular currents and line currents. It is found that for radial pulsations, rotation in general, helps in the dynamical stability of the cosmical bodies.

82. Taylor, H.L.
Satellite orientation by inertial techniques. AEROSPACE SCIENCES v. 28, n. 6,
p. 493-499, 512, June 1961.

Utilizing the properties of the gravitational gradient, an instrumentation system and an orientation procedure are proposed by which satellite attitude control and orbital parameter computation can be accomplished.

83. Thomson, W.T. and Reiter, G.S.
Attitude drift for space vehicles.
JOURNAL OF THE ASTRONAUTICAL SCIENCES
v. 7, n. 2, p. 29-34, Summer 1960.

This paper examines the effect of energy dissipation on a spinning body and evaluates the time required for a body of given configuration to undergo a specified change in attitude.

84. Upton, E., Bailie, A. and Musen, P.
 LUNAR AND SOLAR PERTURBATIONS ON
 SATELLITE ORBITS. National Aeronautics
 and Space Administration, Washington, D.C.
 (Presented at the American Rocket Society
 (New York) 14th Annual Meeting, Washing-
 ton, D.C., 16-20 Nov 1959) Paper 920-59.

A refinement of earlier computations on the orbit of the Vanguard I satellite has revealed the presence of a very slow variation in perigee height, with a period of 449 days and an amplitude of 2 km. It has been suggested recently that a term of this period and amplitude will result from a combination of lunar and solar perturbations on the Vanguard I satellite. Calculations have been extended to the case of the paddle wheel satellite, Explorer VI, which has an apogee of 48,700 km, a perigee of 6640 km and an orbital inclination of 47.3 deg to the equator. It is found that the highly eccentric orbit of this satellite produces substantial lunar and solar perturbations which decrease the perigee altitude rapidly, shortening its lifetime from several decades to a probably value of two years. This paper further explores the possible lunar and solar effects on perigee height for satellite orbits of large eccentricity.

85. Veldkamp, J.
 The activity of the geomagnetic field.
 ICUS REVIEW v. 3, n. 2, p. 97-99, Apr 1961.

The occurrence and cause of the regular daily variation in the geomagnetic field are briefly discussed.

86. Vestine, E.H.
 SOLAR INFLUENCES OF GEOMAGNETIC AND
 RELATED PHENOMENA. Rand Corp., Santa
 Monica, California. Rept. RM-2738-NASA.

Geomagnetic effects of streams of electromagnetic and particle radiation from the Sun are discussed. The interplay of forces between the geomagnetic field and solar streams is outlined, and the theoretical relationship between

86. (cont'd) these, the solar storms, the trapped Van Allen radiations, the polar aurorae, and the geomagnetic field distortion are presented.

87.

Vestine, E.H.

The survey of the geomagnetic field
in space. AMERICAN GEOPHYSICAL UNION,
TRANSACTIONS OF THE v. 41, n. 1, p. 4-21,
Mar 1960.

This paper is concerned with the Earth's geomagnetic field near the Earth and in the surrounding space.

88.

Wyatt, S.P.

THE EFFECT OF RADIATION PRESSURE ON THE
SECULAR ACCELERATION OF SATELLITES.

Smithsonian Institution, Astrophysical
Observatory, Cambridge, Mass. Special
rept. 60, 10 Mar 61.

This study evaluates the effect of solar-radiation pressure on the secular acceleration of Earth satellites. For perigee heights less than about 800 km the period changes due to radiation pressure are minor compared with those due to atmospheric drag. At greater heights and lower air densities, radiation pressure becomes increasingly important. When a satellite is in sunshine all around its orbit, the period change arising from the pressure of sunlight is zero. But during the weeks or months it is penetrating the Earth's shadow and is therefore exposed to a photon wind only part of each circuit, the secular acceleration may attain substantial values, positive or negative, depending on the orientation of the orbit relative to the Sun. Several special cases of orientation are discussed, and a general formula for computing secular accelerations due to radiation pressure is derived as far as terms in the square of the eccentricity.

89.

Westerman, H.R.

Perturbation approach to the effect of
the geomagnetic field on a charged

89. (cont'd) satellite. ARS JOURNAL v. 30, n. 2,
p. 204-5, Feb 1960.

An investigation is reported of the effect of the Earth's magnetic field on the orbit of a charged satellite.

90. Wilson, R.H., Jr.
The bolometric solar related to radiation
pressure effects on satellites. ASTRO-
NOMICAL JOURNAL v. 66, n. 2, p. 58, Mar 1961.

91. Wilson, R.W.
Geomagnetic rotational retardation of
satellite 1959 alpha 1 (Vanguard II)
SCIENCE v. 131, n. 3395, p. 223-225,
22 Jan 1960.

Radio observations indicated rotation speed was retarded exponentially at a rapid rate. Analysis confirms the eddy-current theory previously applied to Vanguard I.

92. Yeh, K.C., and Gonzalez, V.H.
NOTE ON THE GEOMETRY OF EARTH MAGNETIC
FIELD USEFUL TO FARADAY EFFECT EXPERI-
MENTS. Illinois, Univ. of, Electrical
Engineering Research Lab., Urbana.
10 Feb 60.

The geometric factor M involving the Earth's magnetic field in the Faraday effect equation is studied. A total of 48 coefficients is used to compute this factor. Some representative curves are shown. It is found that, in general, this factor is not a constant for a given ray. However, when a ray passes near the saddle point of the "M-surface," M can be assumed to be constant along the ray with reasonable accuracy. In other regions of the

92. (cont'd) sky an empirical average value of M must be used for a given ray and its value depends on the direction of the ray and the a priori ionization density profile. The results are compared with values computed by using dipole Earth field.

93. Zhigulev, V.N. and Romishevskii, E.A.
 Concerning the interaction of currents
 flowing in a conducting medium with
 the earth's magnetic field. SOVIET
 PHYSICS - DOKLADY v. 4, n. 4, p. 859-62,
 Feb 1960. (Trans. of AKADEMIIA NAUK, SSSR,
 DOKLADY v. 127, n. 5. p. 1001, Aug 1959)

In this paper an investigation is made of the motion of the Earth in an orbit passing through interplanetary ionized gas, and likewise of the interaction of the solar corpuscular currents with the Earth's magnetic field. The effect of the possible collective interactions of the particles is taken into account, and also the effects of the mutual influences of the ionization current of the gas and the Earth's magnetic field.

94. Zonov, Yu. V.
 ON THE PROBLEM OF THE INTERACTION
 BETWEEN A SATELLITE AND THE EARTH'S
 MAGNETIC FIELD. National Aeronautics
 and Space Administration, Washington, D.C.
 TT F-37, May 60. (Iskusstennyye Sputniki
 Zemli n. 3, 1959)

This study considers first the currents induced by the translational motion of a satellite relative to the magnetic field, then by the change in the speed of rotation of a satellite about its own axis due to eddy currents, and finally by the disturbing forces exerted by the magnetic field on a satellite that has no rotation of its own.